University of California
Santa Barbara

Panel E: "Mapping a Future for Optical Networking and Communications"

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Workshops on "Mapping a Future for Optical Networking and Communications

- Planning Grant: Dan Blumenthal (UCSB), John Bowers (UCSB), Craig Partridge (BBN)
- Held 2 Workshops
  - Feb 2-3, 2005 (13 participants) and April 12-13, 2005 (47 participants)
- Recommendations in 3 primary areas
  - Foundations
  - Engineering of Devices
  - Networking Systems and Architectures

Recommendations to NSF (1): Foundations

- Build the foundation for photonic integration
- Expand the capacity of single mode fiber
- Advance optical modulation and regeneration capabilities
- Quantum data communications

Recommendations to NSF (2): Engineering of Devices

- PIC CAD Tools
- Programmable photonics
- Cost reduction
- CMOS compatible photonics

Recommendations to NSF (3): Networking Systems and Architectures

- Re-examine our understanding of what optics can do in tomorrow's networking environment
- Architectures that build on transparency and rapid dynamic reconfiguration
- Moving optics from the network into the computer

Key Themes and Issues

- Near term (5 years)
  - Expanding the medium
    - Bridge fiber from the core to the access
    - Include different optical media (multi-mode, wireless)
  - Increasing transparency
    - Open fiber bandwidth to wide range of coding similar to wireless
  - Early steps in photonic integration
    - Design and fabrication of dense photonic integrated circuits (PICs)
  - End to end dynamic networking
    - Move beyond simple fiber circuits, make bandwidth dynamic
  - Moving from rings to meshes
    - More robust, scalable networks, lower cost
  - Network link bandwidth
    - Can continue to increase and drive down cost
  - Increasing modulation efficiency
    - Move beyond the basic on-off keying, more like RF

Key Themes and Issues

- ***Field Programmable PICs (FPPIC).:*** The goal here is twofold: (i) To enable researchers to specify what functions the PIC needs to perform and (ii) to make that function usable or programmable from the electronic control plane or signaling layers.
- ***>100 Gbit optical switching*** with rapid switching times (under 1ns).
- ***Optics on integrated circuit boards***
- ***Breaking down the network-computer boundary***
- ***Rethinking the router:*** We're now at the point where power dissipation is a key issue in router design and high-end routers often occupy multiple racks.
- ***Agile Optical Networks:*** making the optical spectrum a programmable media will invigorate optical device and network research and make optics an accessible technology to the broader network researching community.
- ***Fitting packet switching/routing logic into a PIC***.
- ***Chip level optical buffering***.
- **Photonic CMOS**

Key Problems

- Physical layer scalability
  - Transmission impairments and data degradation
- Lack of sophisticated modulation techniques to increase bits per hertz
- Power consumption and footprint of ultra-high capacity systems (2 Tbps to 256 Tbps)
- Physical layer security
- Low cost design and fabrication of dense photonic integrated circuits (PICs)
- Mature design in of photonic technologies
- Network access techniques that capitalize on optical network bandwidth
- Intelligent, robust control plane technology

Potential Solutions

- Enabling steps for photonic integration
  - Foundry model, design tools, production testing, packaging
- Network Scalability
  - Physical Layer: All-optical regeneration and wavelength conversion
  - Robust control plane technology for dynamic bandwidth
- Power and Footprint
  - Rethinking the router: Optical packet switching
- Agile Optical Networks
  - Making the optical spectrum a programmable media
- Photonics Integration and Design-In
  - Field-programmable PICs
  - CAD to foundry
  - CMOS photonics
- Optical Security
  - Quantum data networks

Recommendations to NSF (4)

- Re-Focused Research Programs
  - Ultra-efficient high bandwidth optical communications and networking
  - Highly integrated photonic network functions and network elements
  - Programmable optics – Integration of photonics and electronics
  - Rapid dynamically reconfigurable optical networks and control plane technology
  - Quantum optical communications technology, systems and networks

Recommendations to NSF (5)

- Experimental Facilities and Infrastructure
  - New network infrastructures that allow deployment of optical network (transmission and node) technology in a manner that allows network researchers to use optics as one of the tools to investigate the scientific underpinnings of new, untested networks and applications. These experimental facilities should enable networking researchers to utilize, through control plane and network control mechanisms, to study network issues that cannot be studied on today's Internet.
  - Funding a new photonics foundry that makes optics a more usable, widely accessible technology to a broader class of network architects and researchers. The foundry should follow the success of MOSIS and bring to bear the vast photonics device resources in the US today and make these resources available to optical device and network researchers.

Key Technologies

- Tunable Lasers
- Wavelength Converters
- Optical Label and Packet Processing
- Optical Packet Switches
- Optical Buffers
- 3R Devices
- Optical/Photonic Device Foundry
- Field Programmable Photonic Devices
- Ultrafast technologies (160Gbps and higher)
- Transmission impairment mitigation
- Multi-level modulation/demodulation
- Quantum encryption and transmission
- Optical performance monitoring

Key Research

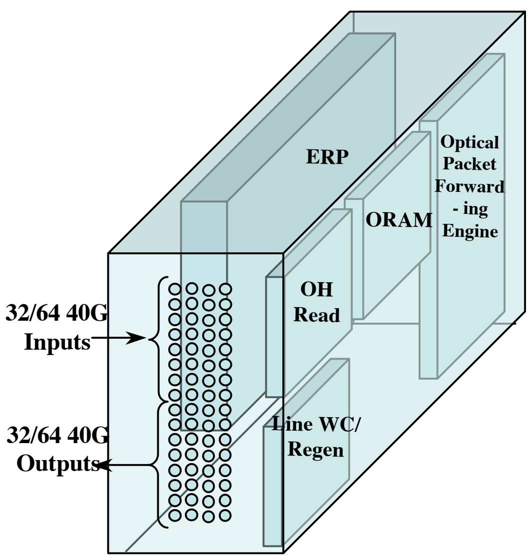
- At UCSB
  - Optical packet switching
  - InP Photonic Integrated Circuits
  - All-Optical Wavelength Conversion and Regeneration
  - Optical Buffers
  - Slow Light
- Research still needed
  - Optical 3R regeneration
  - Transmission impairment mitigation
  - Control plane technology
  - Increased integration density (10x, 100x)
  - Multiwavelength regenerators

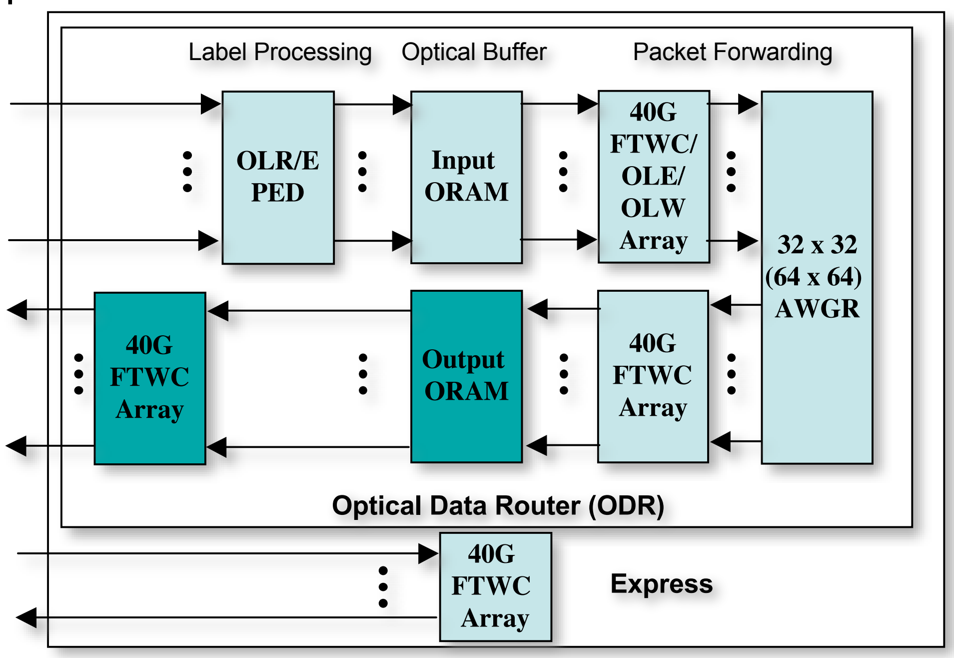
LASOR: Label Switched Optical Router

- **DARPA/MTO: Dr. Jagdeep Shah PM**
- **Project Start Date: 4/8/04**
- **$15.8M 4-Years**
- **Technical Team**
  - **UCSB:** M. Masanovic, V. Lal, J. Summers, H. Poulsen, D. Wolfson, Z. Hu, E. Burmeister, S. Bjorlin, H. Park, J. Chen, A. Tauke-Pedretti, M. Dummer, J. Barton, L. Johansson, M. Davanco, B. Koch, R. Rajaduray, R. Doshi, W. Zhao, D. J. Blumenthal, J. E. Bowers, L. A. Coldren, E. Hu
  - **Agility Communications:** C. Coldren, G. Fish
  - **Calient Networks:** O. Jerphagnon, R. Helkey, S. Yuan
  - **Cisco Systems:** G. Epps, D. Civello, P. Donner
  - **JDS Uniphase:** D. Al-Salameh
  - **Stanford University:** Y. Ganjali, N. McKeown, T. Roughgarden, A. Goel

1.28 (2.56) Tbps Linecard

- Basic linecard contains an optically buffered ODR with
  - Optical label read/erase/re-write
  - Packet forwarding
  - Output line wavelength conversion and regeneration
- 1.28 Tbps achieved with 32 x 32 forwarding fabric
- 2.56 Tbps can be achieved with potential 64 x 64 forwarding fabric
- Linecard design adaptable for different router architectures





Key Challenges

- Key technical challenges
  - High yield InP photonic circuits
  - Low loss optical waveguides
  - Low cost packaging
  - Optical Buffers
- Key external challenges
  - National Foundry Facilities
  - National Experimental Networks
    - Layer 1 and up needed

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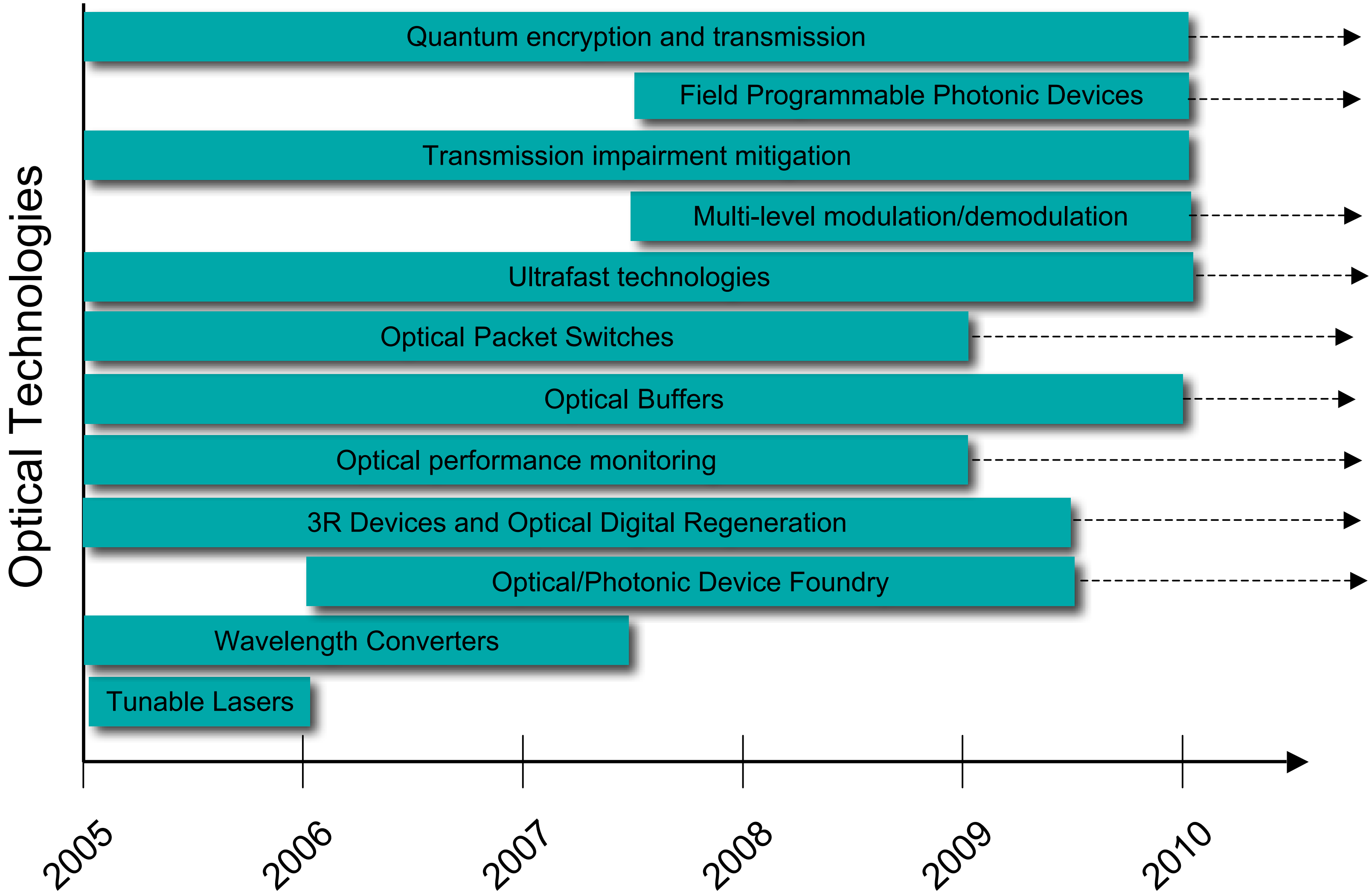
Roadmap: Optical Technologies



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Roadmap: Optical Network Based Services